V. Finally, the importance of collateral reading in the masterpieces of biological literature is strongly emphasized.

At the St. Louis meeting of the American Association of Anatomists, December 29, 1914, the report of the committee on premedical work in biology was approved by the association; and the committee was continued with instructions to submit the approved report to the zoologists, and to secure their cooperation in carrying the work further.

H. McE. KNOWER, *Chairman*

SPECIAL ARTICLES

SEX DETERMINATION AND SEX CONTROL IN GUINEA-PIGS

THE observations, a short exposition of which is given here, were made on guinea-pigs, being used by Professor Stockard in heredity experiments. He very kindly placed the material at my disposal for this study, and I wish to express my appreciation of this favor.

These observations show that the sex of a guinea-pig is determined sometimes by two and sometimes by three factors, depending upon whether the mother has previously born young.

The first factor "A" is the sex tendency of the father. If the father has a male sex tendency, his sons will have a female tendency and his daughters a male tendency. If, on the contrary, the father possesses a female tendency, his sons will have male tendencies and his daughters female tendencies. In other words, sons exhibit the opposite and the daughters the same tendency as the father.

The second factor "B" is the sex tendency of the mother. A mother with a male tendency gives her daughters a female and her sons a male tendency. The mother with a female tendency gives her daughters a male and her sons a female tendency. Thus the transmission of the sex tendency from the female is also criss-cross in the same fashion as that of the male. The females inherit like tendencies from their father and the males like tendencies from their mother, whereas the males inherit the reverse tendency of their father and the females the reverse tendency of their mother.

The third factor "C" is confined to the female and is a change of sex tendency from litter to litter. This change in tendency manifests itself in the following way:

If the first litter contains only males, the mother acquires a female tendency for the next litter and vice-versa. This new tendency varies in strength, depending upon the number of young of one sex contained in a litter. The greater the number of males in a litter, the stronger the female tendency will be for the next litter. This tendency is still more emphasized if the mother is successively mated with males of a definite tendency, and therefore forced to produce more and more young of one sex.

The tendency of the various animals of a certain stock must first be ascertained in an experimental manner; given a number of undetermined males and females, each male must be mated with all the females and each female with all the males. After all the animals have been tested in this way, the results will show more males from some animals and more females from others. If, now, the offspring from these matings be grouped so as to take those animals which have come from more male producing fathers and their tendency be tested, it will be found that from the males more females will be produced and from the females more males. Provided the determination of the sex tendency for the first set of animals was absolutely correct, and if there was no other factor in action, the proportion of males to females should be as 75 : 25 from male producing males mated with females having different tendencies, and from female producing males the proportion is reversed. It is, however, very difficult to determine absolutely the sex tendency of an animal after only a few matings, and for this reason, some animals supposed to have a male tendency will probably have a weak female tendency, and *vice versa*.

In order to find with reasonable definiteness

the tendency of animals, the tendency of the ancestors for three or more generations should be known. It must also be recalled, as explained above, that the third factor "C" in the female reduces the difference between the ratio numbers of her male and female descendants. As a result of this, the difference between the number of males and females considering only mother tendency is smaller than the difference between males and females in the light of only the father tendency. A male has a male tendency or a female tendency and always maintains it, whereas the female has a born male or female tendency, but in addition to this she has a second tendency to change her sex tendency from litter to litter. The number of males and females derived from the second generation was as follows:

I. Descendants of males whose fathers had a male tendency mated with mixed females; 39 males to 54 females, *i. e.,* 41.94 per cent. males to 58.06 per cent. females (sex ratio 72.20).

II. Descendants of males whose fathers had a female tendency mated with mixed females; 42 males to 23 females, *i. e.,* 64.61 per cent. males to 35.39 per cent. females (sex ratio 182.60).

III. Descendants of males whose mothers had a male tendency mated with mixed females; 64 males to 53 females, *i. e.,* 54.70 per cent. males to 45.30 per cent. females (sex ratio 120.83).

IV. Descendants of males whose mothers had a female tendency mated with mixed females; 12 males to 13 females, *i. e.,* 48 per cent. males to 52 per cent. females (sex ratio 92.30).

V. Descendants of females whose mothers had a male tendency mated with mixed males; 13 males to 18 females, *i. e.,* 41.94 per cent. males to 58.06 per cent. females (sex ratio 72.22).

VI. Descendants of females whose mothers had a female tendency mated with mixed males; 51 males to 43 females, *i. e.,* 54.25 per cent. males to 45.75 per cent. females (sex ratio 118.60).

VII. Descendants of females whose fathers had a male tendency mated with mixed males; 38 males to 36 females, *i. e.,* 51.38 per cent. males to 48.62 per cent. females (sex ratio 105.55).

VIII. Descendants of females whose fathers had a female tendency mated with mixed males; 33 males to 37 females, *i. e.,* 47.15 per cent. males to 52.85 per cent. females (sex ratio 89.18).

These figures show that in the sons the tendency received from the father is stronger than that coming from the mother, while in the daughters the opposite is true.

When one examines the descendants of animals whose fathers had a male tendency and mothers a female tendency, a higher difference in the relative number of males and females is found than from those cases in which the fathers alone had a male tendency. Twenty descendants of such male animals (father male tendency and mother female tendency) mated with mixed females consisted of four males and sixteen females, *i. e.,* 20 per cent. males and 80 per cent. females (sex ratio 25.00). From the females of the same type (father male tendency and mother female tendency) mated with mixed males, 29 males and 15 females were derived, *i. e.,* 65.90 per cent. males to 34.10 per cent. females (sex ratio 193.33).

From the second-generation males whose fathers had a female tendency and whose mothers show a male tendency when mated with mixed females were derived 32 males and 15 females, *i. e.,* 68.08 per cent. males to 31.92 per cent. females (sex ratio 213.33). From the females of the same type (father female tendency and mother male tendency) mated with mixed males were derived 6 males and 13 female descendants, *i. e.,* 31.58 per cent. males to 68.42 per cent. females (sex ratio 46.15).

Should one select males whose fathers had a female tendency and whose mothers had a male tendency and mate these with females whose fathers had a male tendency and whose mothers had a female tendency, a higher difference in the relative number of males and

females will be found in their descendants than in any other possible case. From such combinations were derived nine animals, all males. In the same way, from the combination a male derived from a father, male tendency, and mother, female tendency, mated with a female from father, female tendency and mother male tendency, were derived six animals all of which were females.

This regulation in the inheritance of the sex tendency is especially interesting in affording an explanation of the manner in which the equilibrium is maintained between the number of male and female offspring of a given species. With each new generation each male animal has an opposite tendency from that of his father and each female animal an opposite tendency from that of her mother. It, therefore, follows that a disturbance of the equilibrium in one generation will tend to be restored by the opposite tendencies in the following generation. The above-mentioned change of sex tendency from litter to litter in the female leads to the same result. This third factor "C" regulates equilibrium from birth to birth so that any disturbance of a great degree is impossible.

The difference in the proportion between the sexes in different species may be due to the fact that in some species the father and mother have an equal influence on the determination of the sex of their offspring while in other species either the father or the mother may have the greater influence.

When father and mother have equal influence, the combination father, male tendency, with mother, female tendency, will give equal number males with females tendencies and females with male tendency, and the combination father, female tendency, with mother, male tendency, will give equal number males with male tendency and females with female tendency. In this way equal numbers of male and female descendants will be produced and equal numbers of the descendants will have male and female tendencies. In such a case the sex ratio should be 100 per cent. Should, on the other hand, the mother have the greater influence on the determination of sex, as seems to be the case in the guinea-pigs, then the number of descendants with a male tendency will be greater than the number of those having a female tendency, as the following scheme shows:

Father with male tendency mated with mother with female tendency will give more females (male tendency) than males (female tendency).

Father with a female tendency mated with a mother with a male tendency gives more males (male tendency) than females (female tendency). Therefore from either combination the greater number of offspring have a male tendency and as a result of this the sex ratio will be greater than 100.

In guinea-pigs it really seems that the influence of the mother is greater than that of the father, and this may be the explanation of the fact that the number of male guinea-pigs is greater than the number of females.

Finally, if the father has a greater influence on sex determination than the mother the number of descendants with a female tendency will be greater than the number with a male tendency, and consequently the sex ratio will be smaller than 100, as is shown by the following analysis:

Father with male tendency mated with mother with female tendency gives more males (female tendency) than females (male tendency). The father with female tendency mated with mother with male tendency gives more females (female tendency) than males (male tendency). Thus from either combination the greater number of offspring have a female-producing tendency and as a result of this the sex ratio will be less than 100.

Concerning the third factor, "C," the change of the sex tendency from litter to litter, a statistical examination shows the following results:

First: Relative number of male and female descendants after the birth of one or more females in one litter; 38 males to 12 females, *i. e.*, 76 per cent. males to 24 per cent. females (sex ratio 316.66).

Second: Relative number of male and female descendants after birth of one or more

males; 13 males to 38 females, *i. e.,* 25.49 per cent. males to 74.51 per cent. females (sex ratio 34.21).

To determine further whether the sex-tendency of males showed any inclination to change from mating to mating the records were counted in the following manner:

Taking the matings of given males following matings that produced only female young, it was found that the product of such matings consisted of 22 males to 27 females, *i. e.,* 44.90 per cent. males to 55.10 per cent. females (sex ratio 81.48).

Taking the matings of given males following matings that produced only male young, it was found that the product of such matings consisted of 28 males to 24 females, *i. e.,* 53.84 per cent. males to 46.16 per cent. females (sex ratio 116.66).

This result is therefore the reverse of that shown by the females. Whereas the females show an opposite tendency following each litter, the males always maintain the same tendency.

Only those litters which were purely male or female were used in the above consideration. After a mixed litter of males and females, which is more common under natural conditions, there is not a pure, but also a mixed sex tendency. This fact renders the recognition of the "C" factor extremely difficult.

Such a characteristic change in tendency from birth to birth also seems to occur in other animals. The daphnids, for instance, seem to have some such regulation very definitely expressed.[1] In these organisms also the sex tendency changes from generation to generation as well as from birth to birth in such a way that not after each generation and each birth, but after a number of generations and births, differing with different species, the exclusive production of parthenogenetic female ceases and the first males appear. Doubtless we have in this an example of a change of the sex tendency, but its expression is quite different from that in the guinea-pigs.

[1] Papanicolaou, G., "Experimentelle Untersuchungen über die Fortpflanzungsverhältnisse der Daphniden," *Biol. Zentralbl.*, 30, 1910.

From a theoretical standpoint, it is very important that coincidentally with the change of sex tendency in the summer eggs from female to male in *Moina rectirostris* var. *Lilljeborgii,* there is also a change in the color of these eggs from violet to blue.[2] This fact probably indicates that some chemical change occurs in the eggs at the same time that the change in the sex tendency takes place.

At the present time I am endeavoring to complete my observations and to determine statistically the relative value of the three factors in different combinations. Since, however, the animals at my disposal are designed especially for the study of the degenerative influence of alcohol, it will, no doubt, require a long period of time to collect hundreds of selected cases, since so few animals of the generations later than the third are capable of reproduction.

This preliminary report is published with the hope that other investigators, having a large stock of different animals at their disposal, may further contribute to the solution of this problem in all its details.

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THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

SECTION C

The first session was held on the afternoon of Thursday, December 31, at the John Harrison Laboratory of Chemistry, Vice-president Edgar F. Smith in the chair, with an attendance of about 75. The following officers were elected:

Vice-president—William McPherson, Ohio State University.

Member of Council—W. T. Taggart, University of Pennsylvania.

Member of General Committee—L. W. Jones, University of Cincinnati.

Member of Sectional Committee—E. C. Franklin, Stanford University.

The section passed a resolution to the following effect: That the committee of Section C endeavor

[2] *Ibid.*